Rebuttal Expert Report:
Limitation of Dust
Sampling Methodology

Project LSH505344

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Rebuttal Expert Report

1.0 Introduction

Two expert reports were submitted by plaintiff's experts related to surface dust sampling. These reports (one by Dr. W. Longo and another by W. Ewing) purport to show that dust sampling has a long and established history, is a scientifically reliable method, and is useful in evaluating health risks. Of these three points, the issue of whether the method is scientifically reliable is the primary issue. Health risks can only be properly interpreted when the risk data are developed using reliable analytical procedures. The microvacuum method is flawed, in large part, because it modifies the sampled particles, altering the manner in which the particles were found on the surface and removing asbestos fibers from any matrix materials in which they were bound.

2.0 Scientific Reliability of the Method

The primary question to be answered is whether the method is scientifically reliable. Longo suggests the method has been favorably peer reviewed and has been tested to show an acceptable degree of reproducibility. Contrary to these opinions, the method has been unfavorably peer reviewed and has been shown to have a built-in, uncontrolled bias and is inherently non-reproducible.

The basic tenets of the microvacuum method have been reviewed by Lee[1,2], Kauffer[3], Sahle[4], Chatfield, and others. Each of these reviews has shown the method to be an unreliable procedure for evaluating the number concentration of asbestos fibers in surface dusts. The reviews referenced by Longo (references 1, 3-7, and 9-11 on page 12 of Longo's report) were

[1] Lee, R. J.; Dagenhart, T. V; Dunmyre, G. R.; Stewart, I. M; and Van Orden, D. R. (1995). "Effect of Indirect Sample Preparation Procedures on the Apparent Concentration of Asbestos in Settled Dusts", *Environmental Science & Technology*, 29, p. 1728 – 1736.

[2] Lee, R. J.; Van Orden, D. R.; Dunmyre, G. R.; and Stewart I. M. (1996). "Interlaboratory Evaluation of the Breakup of Asbestos-Containing Dust Particles by Ultrasonic Agitation", *Environmental Science & Technology*, 30, p. 3010 – 3015.

[3] Kauffer, E., Billon-Galland, M. A., Vigneron, J. C., Veissiere, S., and Brochard, P. (1996). "The Effect of Preparation Methods on the Assessment of Airborne Concentration of Asbestos Fibers by Transmission Electron Microscopy". *Annals of Occupational Hygiene*, 40, p. 321 – 330.

[4] Sahle, W., and Lazlo, I. (1996). "Airborne Inorganic Fibre Level Monitoring by Transmission Electron Microscopy (TEM): Comparison of Direct and Indirect Sample Transfer Methods". *Annals of Occupational Hygiene*, 40, p. 29 – 44.

conducted either by Longo's laboratory or by experts routinely retained by plaintiffs in property damage litigation.

The issues related to the microvacuum technique are illustrated by testing conducted on simulated building dusts. In each of these tests, the surface dust deposition was controlled so that a uniform layer of dust was generated for later sampling and analysis.

Crankshaw[5] created "dust" using calcium carbonate and chrysotile asbestos, mixed those materials in known concentrations, and distributed them in a dust chamber for later microvacuum sampling and analysis. Even with a uniform deposition of dust, Crankshaw's data show there is a 75% variability[6] in the asbestos structure counts.

Lee (reference 2) also tested a simulated building dust by mixing a reference clay/quartz material with approximately 1 kg of building dust collected from a building with asbestos-containing sprayed-on fireproofing. The mixed material was blown around a room in which various surfaces (ceiling tiles, wood, and carpet) had been placed. Samples collected from the ceiling tile and analyzed by a single laboratory show up to 57% variability of the asbestos structure counts.

Therefore, the data show that even with uniformly deposited "dusts", the sampling methodology employed by Claimants' experts yields substantial differences in analytical results (57 to 75% variability).

What components of the methodology produce such scientifically unacceptable results? The dust sampling techniques can be divided into sample collection, sample preparation, and sample analysis. Of these three parts, sample collection and sample preparation generate bias and non-reproducibility.

2.1 Sample Collection

A handheld sampling pump is used to vacuum the surface dust from a defined area into a cassette. As noted in the method, the sample area is "vacuumed until there is no visible dust or particulates matter remaining". However, the sampling technician is to "[a]void scraping or abrading the

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[5] Crankshaw, O., Perkins, R. L., and Beard, M. E. (1996). "Quantitative Evaluation of the Relative Effectiveness of Various Methods for the Analysis of Asbestos in Settled Dust", *EIA Technical Journal*, 4, p. 6 – 12.

[6] Order-of-magnitude confidence intervals (intervals that range from 0 up to twice the reported value) on the average value of side-by-side samples require the sample variability to be no more than 11% for paired samples and no more than 40% when three samples are collected. For tighter (smaller) confidence intervals, lower levels of variability are required. ASTM is currently writing a guidance document for surface dusts (WK7719) where a 7% variability is used for example calculations.

surface being sampled". Particles larger than 1 mm are not to be collected. (Step 8.7 of D5755).

Microvacuuming is not performed consistently between different investigators, leading to differences in asbestos structure counts. In a sampling event conducted by Ewing and Van Orden at several Illinois universities, a particular window ledge was selected by Ewing for one sample collection event. The window ledge was on an inside window where Coca-Cola had been spilled (the can was on the window ledge). A section of the dried cola was completely sampled by Ewing, leaving no remaining cola or surface dust on the painted surface. On an area immediately adjacent, the sample collected under the direction of Van Orden could not remove the dried cola. The attached photograph, Figure 1, illustrates this difference in sample collection.

Two additional Figures show the differing degrees of particle collection by two sampling teams collecting from the same surface. In both photographs, the differences in sampling are visually apparent.

Figure 1. Photograph of the location of side-by-side microvacuum sampling collected by different personnel. The window ledge is on an interior wall where cola had been spilled and dried. The sample on the right scraped through the dried cola while the sample on the left scratched the surface but did not penetrate the dried cola.

Figure 2. Side-by-side samples collected on top of a projection screen by different personnel. Both samples scraped the surface, but the top sample cleaned the surface more thoroughly than the bottom sample.

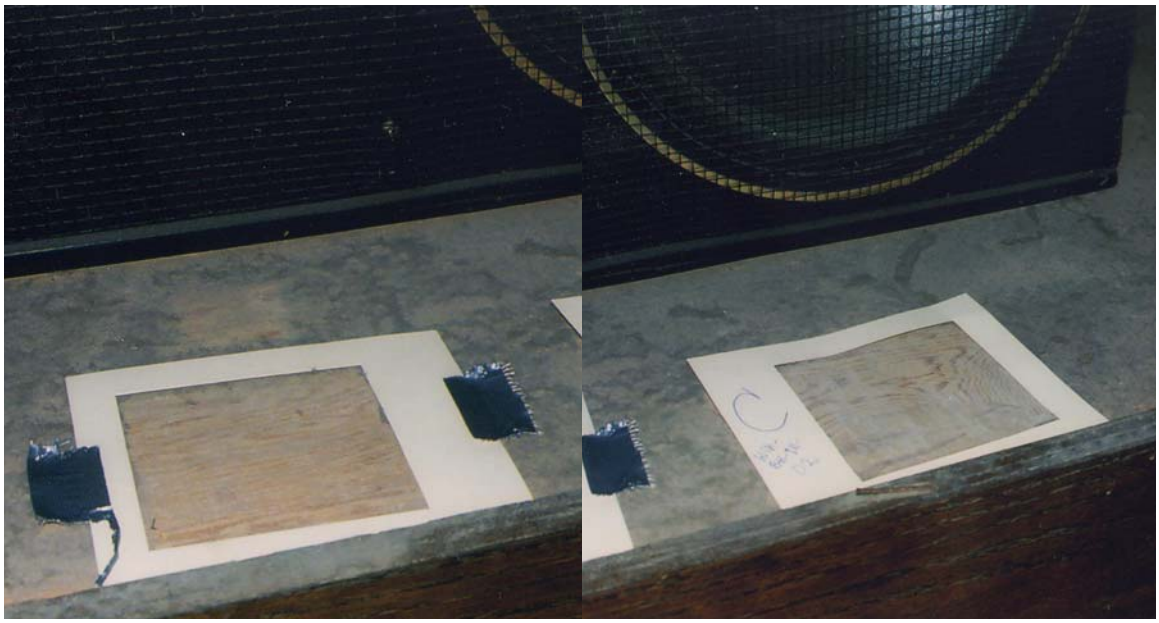

Figure 3. Side-by-side samples collected on a canopy located in a dining hall. The sample on the left removed more material than the sample on the right.

As evident in all three pictures, neither team collected the samples in accordance with the published method which states: "Avoid scraping or abrading the surface to be sampled."[7]

Thus, the process of collecting a microvacuum sample is not well defined nor is it applied in a consistent manner among individuals. These differences lead to variations in the reported asbestos structure counts.

[7] ASTM (1995). "Standard Test Method for Microvacuum Sampling and Indirect Analysis of Dust by Transmission Electron Microscopy for Asbestos Structure Number Concentrations", Section 8.8.

2.2 Sample Preparation

The most widely discussed and criticized aspect of microvacuum sampling is the sample preparation portion of the method. Briefly, the preparation method encompasses the following steps: 1) rinse the dust out of the sampling cassette using an aqueous solution, 2) sonicate the suspended particles, 3) redeposit an aliquot of the sonicated particles on a clean filter, and 4) prepare the redeposit filter for analysis.

The most disruptive step in sample preparation is the sonication of the sample. During sonication, high frequency sound energy is transmitted through the liquid suspension causing cavitation. Cavitation is the formation of microbubbles that, when they collapse, cause shock waves to travel through the liquid at nearly the speed of sound. At the microscopic level, sonication is a highly disruptive force that, as noted in the ASTM D5755 method, "is intended to disperse aggregated asbestos into fundamental fibrils, fiber bundles, clusters, or matrices" and "may alter the physical form of the mineral fibers".

Sonication produces uncontrolled results. No U.S. promulgated analytical method for examining air filters in buildings or for evaluating worker risk to airborne asbestos uses an indirect preparation procedure. Similarly, because of this uncontrolled effect of sonication, the official air sample procedure for France forbids the use of sonication even though the method utilizes an indirect preparation procedure.[8]

The US EPA has published a study on the effect of the indirect preparation method.[9] As noted in the Executive Summary: "… measurements made by the indirect transfer method were 3.8 times to 1,700 times higher than measurements made by the direct transfer method." Also: "There is no single factor that can be applied to convert measurements made using an indirect transfer method to a value that is comparable with measurements made using a direct transfer method."

Dr. Longo contends the use of the indirect sample preparation procedure for the microvacuum method was "chosen to provide better precision and reproducibility than if the direct method were used." In fact, it was chosen because the microvacuum sampling method required that (at a minimum) enough dust be collected to darken the sample filter, thus precluding any direct preparation of the sample.[10] A filter will darken during sample

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[8] Norme Française (1996). "Qualité de l'air: Détermination de la concentration en fibres d'amiante par microscopie électronique à transmission", NF X 43-050.

[9] EPA (1990). "Comparison of Airborne Asbestos Levels Determined by Transmission Electron Microscopy (TEM) Using Direct and Indirect Transfer Techniques", EPA 560/5-89-004, p. x.

[10] Clark, P. and Brackett, K. (1990). "Draft Test Method for Sampling And Analysis of Dust for Asbestos Structures by Transmission Electron Microscopy", US Environmental Protection Agency. As stated in

collection as more and more particles are collected. These particles will overlap, or lay upon each other, obscuring the white filter media. Because the particles are covering other particles, some collected asbestos fibers may also be obscured or covered. Thus, a direct preparation of the sample will not be able to detect these obscured fibers.

The microvacuum procedure permits the analysis of particles as large as 1 mm. The effect of processing such large particles was shown in a study in which a single large particle of chrysotile asbestos was submitted to various laboratories for analysis. (Lee reference 2) The results of these tests showed that a single large particle of chrysotile can generate anywhere from 20,000 to 22,000,000 s/cm^2 based on a sampling area of 100 cm^2. Similarly, wide ranges of results were obtained when analyzing either a 0.5 mm particle of asbestos-containing fireproofing (1,000 to 630,000 s/cm^2) or a 1 mm particle of the same asbestos-containing fireproofing (20,000 to 3,000,000 s/cm^2). These large differences in results illustrate the uncontrolled nature of the sonication procedure.

The cause of these tremendous increases in the number of particles (from one particle to millions in the above examples) is the liberation of bound fibers from matrices and the comminution of the liberated fibers into shorter, more numerous fibers. The liberation aspect is proven by the testing of the 1 mm and 0.5 mm particles of an asbestos-containing fireproofing (noted above) as well as by videotapes[11] of the sonication of particles. Even one of the Claimants' expert microscopists in the Armstrong proceeding has acknowledged that the use of the sonication procedure increases the number of asbestos fibers.[12]

RJ Lee Group has shown how sonication changes the size of asbestos fibers. Lee showed that longer sonication times produced shorter fibers (Lee reference 1). In another test, air filters collected within a single building were randomly selected for analysis by either direct preparation or indirect preparation. After a large number of filters were prepared and analyzed, the data were collated and plotted as shown in Figure 4. In this data set, between 50 and 60% of the indirectly prepared fibers were shorter than 1 µm while only 20% of the directly prepared fibers were shorter than 1 µm. The indirect preparation procedure clearly reduced the length of the fibers.

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section 8.9: "For the method to be effective, enough dust or particulate should be collected within the cassette to be visible to the naked eye."

[11] RJ Lee Group, Inc. (1993). Videotape, Ultrasonic Breakup of Chrysotile Grade 7M and Fireproofing, March 2, 1993.

[12] Keyes, D. L.; et al (1991). "Exposure to Airborne Asbestos Associated with Simulated Cable Installation Above a Suspended Ceiling", American Industrial Hygiene Association Journal, 52, p. 479 – 484. "Moreover, sonication of ashed samples may disassociate bundles and clusters and disassemble matrices, thereby increasing the total number of structures counted."

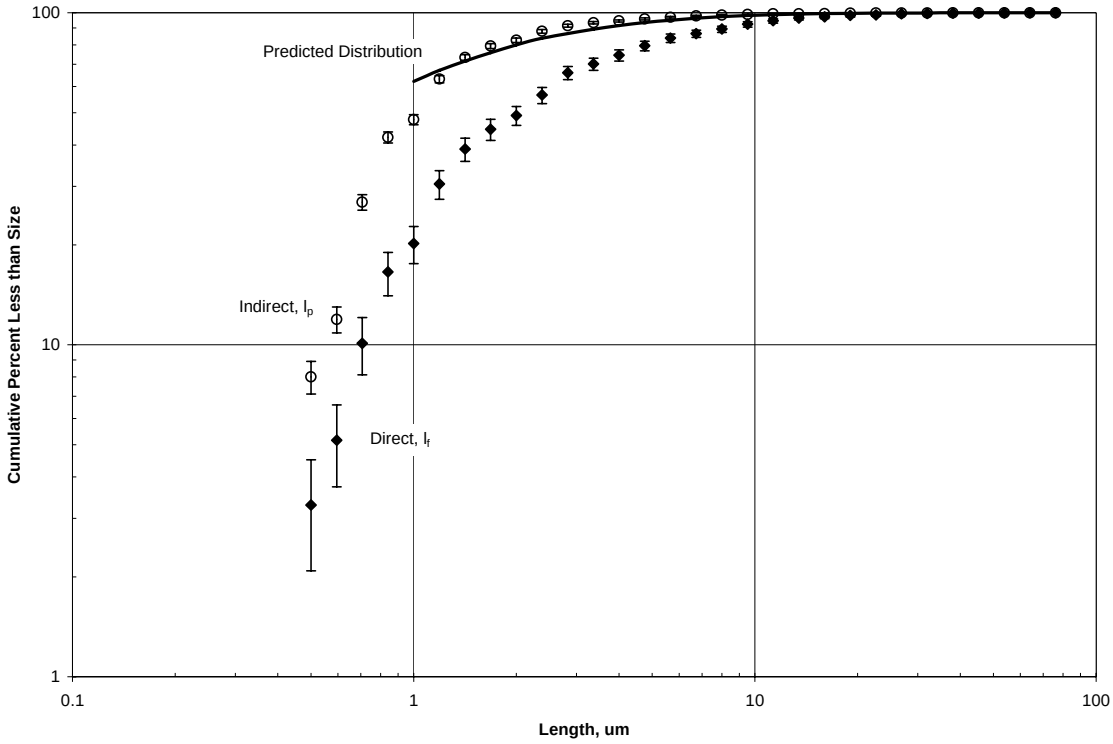

Figure 4. This graph shows the percentage of fibers that are shorter than a stated length. The Directly prepared fibers are solid circles; the indirectly prepared fibers are open circles. Error bars are plotted around each data point.

3.0 Method Reproducibility

As noted above, interlaboratory testing (sometimes referred to as "round robin" testing) of the method has shown the method to have a very large variability, enough to classify the method as non-reproducible for normal building dusts.

Dr. Longo simply asserts that round robin testing of the dust method shows it to be reproducible. Unfortunately, Dr. Longo failed to explain that all of the round robin tests conducted by MAS or on behalf of the ASTM committee are fundamentally flawed – none of the tests actually tested the entire microvacuum method. All of the round robin testing conducted by ASTM[13] was conducted on artificially prepared filters in which the test particles were subjected to sonication and deposition on filters, then sent to the participating laboratories. Therefore, the sonic disaggregation of the particles occurred prior to sending the particles to the laboratories, thus

[13] ASTM (2002). "Draft: ASTM Research Report No. xxxy for D5755". The report only mentions five rounds of testing, not the six mentioned by Dr. Longo. M. Beard, the committee chairperson, confirmed in a telephone conversation 12/13/05, that he has no report for a sixth round, only for five rounds.

effectively removing this important step in the procedure from any round robin examination.

Dr. Longo uses his own sample data[14] to suggest the method has good reproducibility. Yet, in the two sets of data discussed in his publication, the first set used a calculation procedure not permitted by the ASTM method. In the second set of data, Dr. Longo calculated the variability of the microvacuum results from within each of 38 buildings. He then averaged the 38 calculated variabilities, erroneously assuming that the resulting average is a scientifically valid representation of both the variability due to microvacuum sampling and analysis as well as the variability due to the heterogeneous nature of building dusts. In fact, it represents neither.

Dr. Longo did not measure the variability due solely to microvacuuming and vastly underestimated the variability due to the heterogeneous nature of building dusts. As noted on page 3 of this report, even with supposedly uniform dust distribution, the dust methodology results in an unacceptably high 57 – 75% variability in the data. Even assuming the microvacuum sampling technique does not materially affect the reported data, the second data set (from Hatfield, et al, reference 14) significantly underestimates the variability within the building.

As shown in Figure 5, Dr. Longo understated the variability within a building by not collecting enough samples to produce scientifically valid and reliable data. Had he collected 11 samples in every building (as in Building 1 of his data), then the variability would have been much larger than the reported 97%, possibly approaching the 214% reported for Building 1.

[14] Hatfield, R., Krewer, J., and Longo, W. E. (2000). "A Study of the Reproducibility of the Micro-Vac Technique As A Tool for the Assessment of Surface Contamination in Buildings with Asbestos-Containing Materials", *Advances in Environmental Measurement Methods for Asbestos*, ASTM STP 1342, M. Beard and H. Rook, Eds., American Society for Testing and Materials, p. 301 – 312.

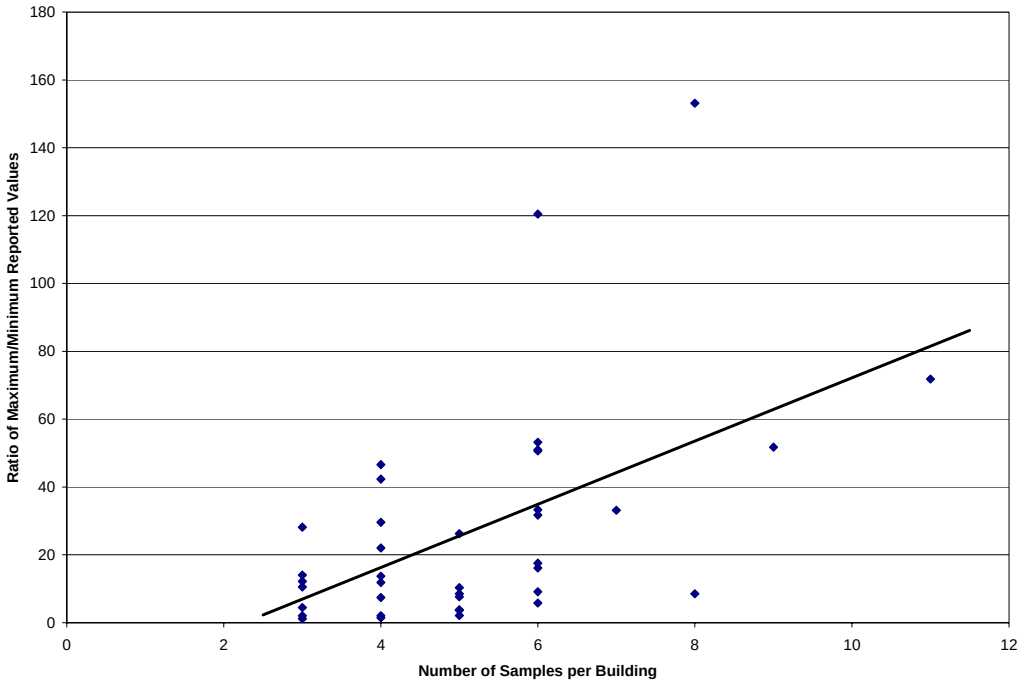

Figure 5. This graph shows that as more samples were collected and analyzed, the greater the range of data that were produced. The data were taken from Hatfield, et al.

Dr. Longo has also misinterpreted the results reported by Crankshaw, et al.[15] In that study, side-by-side samples in a basement indicated a nearly double increase in asbestos loading. Over the entire basement, the data were highly variable with one sample reporting 100 times as much asbestos as the first sample. In tests on lab-created samples, Crankshaw reported 20 times as much asbestos in one set of samples compared to another set, despite there being a 10-fold difference in deposited material.

Crankshaw also conducted a test where he deposited three times as much material in one area compared with another. In this test, the average reported result only increased by a factor of 30%. This increase in reported fiber loading occurred even though the amount of chrysotile deposited on the surface had increased by a factor of 300%. This further illustrates the unreliability of the test procedure.

[15] Crankshaw, O., Perkins, R., and Beard, M. E. (2000). "An Overview of Settled Dust Analytical Methods and Their Relative Effectiveness", *Advances in Environmental Measurement Methods for Asbestos*, ASTM STP 1342, M. Beard and H. Rook, Eds., American Society for Testing and Materials, p. 350 – 365.

4.0 Method Development

Dr. Longo has suggested that the development of the ASTM microvacuum method consisted of nothing more than simple modifications of some non-technical issues. Dr. Longo further recalls that the "basic analytical procedure for preparing and analyzing surface dust samples did not change from the time it was first presented to the ASTM subcommittee in 1990 until its approval in 1995". Dr. Longo is incorrect in both his timeline and his recollection of the changes to the method. The following table documents some of the substantive revisions to the sample preparation portion of the method as it was developed by ASTM, beginning with the EPA draft method:

Item	EPA	6/7/89	12/5/89	1/23/91	10/1/91	11/12/91	4/9/93	1/28/94
Suspension	Ultrapure water	Ultrapure water	Ultrapure water	Ultrapure water	Ultrapure water	Ultrapure water	Ultrapure water	Particle free water and reagent alcohol
pH adjustment	1% HCl	none	1% HCl	1% HCl	1% HCl	1% HCl	1% HCl or 10% Acetic acid	10% Acetic acid
Hand Shaking, s	none	30	30	"briefly"	"briefly"	"briefly"	"briefly"	2 – 3
Sonic bath, W	"Low power"	none	"Low Power"	"Low Power"	100 – 200	60 – 100	100	100
Sonication Time, min	10	none	10	3	3	3	3	3

As can be seen from the Table, substantial changes were made to the sample preparation portion of the method during its development. These are not simply "non-technical" changes. The change from Ultrapure water to a mixture of water and alcohol was made to reduce the dissolution of gypsum in the dust samples, as acknowledged by Dr. Longo in his report (page 21: using alcohol "has the effect of not dissolving any gypsum particles or mixtures"). Similarly, the change from hydrochloric acid to acetic acid was also made to reduce the dissolution of gypsum and carbonate minerals. The sonication of the suspension changed from none to 10 minutes to three minutes. All of these changes are technical and significant. In addition, because the effect of sonication was considered to be a critical element in the method, a calibration procedure for the ultrasonic bath was added following the balloting of the 1/28/94 edition.

5.0 Use of the Microvacuum Method

The legitimate use of the microvacuum method is to document the presence or absence of asbestos fibers in surface dusts. RJ Lee Group used the method in three large projects to document the extent of asbestos in surface dust in three office buildings (Delaware Trust, 130 Liberty Street, and 4 Albany Street buildings). That testing was done in connection with insurance claims to restore the buildings to their pre-event (a fire and the collapse of the World Trade Center) conditions. In each case, the microvacuum sampling was conducted to document that dust and debris had been spread throughout each building as a result of an event and was not present as a pre-event condition. In none of these buildings was the dust sampling performed to evaluate occupant or worker safety.

In contrast, Claimants' experts incorrectly purport to use the microvacuum method for dual objectives: 1) to document the extent of asbestos in surface dust in a building (and relative amounts of asbestos); or 2) to assess the "safety" of building occupants to possible exposure to asbestos-containing surface dusts.

The Claimants' experts unscientific use of the D5755 method to determine "safety" or levels of building "contamination" is seriously flawed due to the use of the indirect preparation procedure and disregards several explicit cautions set forth in the D5755 method. As noted in the method: "as with all indirect sample preparation techniques, the asbestos observed for quantification may not represent the physical form of the asbestos as sampled". (A similar statement was included in the EPA draft microvacuum method.) More specifically, the method states: "no relationship has been established between asbestos-containing dust as measured by this method and potential human exposure to airborne asbestos". The D5755 method also "does not describe procedures or techniques required to evaluate the safety or habitability of buildings with asbestos-containing materials, or compliance with federal, state, or local regulations". The uncontrolled increase in the number of fibers through liberation and comminution makes the interpretation of the asbestos structure counts impossible.

All current risk analyses procedures incorporate direct preparation of the air filters – there is no promulgated risk analysis procedure for the evaluation of asbestos in surface dusts. Even when the EPA developed a risk analysis procedure for soils and bulk materials[16], the method was devised so that the analyzed samples were directly prepared air filters, not indirectly prepared filters.

[16] Berman, D. W. and Kolk, A. (2000). "Draft: Modified Elutriator Method for the Determination of Asbestos in Soils and Bulk Materials", Revision 1, May 23, 2000.

Because the indirect preparation procedure liberates (releases) fibers from any binding matrix, the asbestos structure counts are meaningless in terms of possible exposure.

Both Dr. Longo and Mr. Ewing suggest that the US Environmental Protection Agency (EPA) is using the microvacuum method to "make nearby buildings safe for occupancy" (Longo, page 10) at the World Trade Center. However, the COPC Committee[17] "elected against setting benchmarks for COPC [contaminants of potential concern] in settled dust", particularly for asbestos, because asbestos fibers "exert their toxicity primarily through the inhalation route of exposure". No health-based benchmarks were established for asbestos in surface dusts at the WTC site. Any benchmark created for the WTC site is strictly limited to the WTC site and is not applicable to other buildings.

Mr. Ewing suggests that RJ Lee Group agrees with the use of microvacuum test concentrations in the WTC vicinity by referring to a 2002 *USA Today* article. This reference is a misquote by the reporter who used a comment made by Dr. Lee about high airborne concentrations (reported by Chatfield[18]), not asbestos in dust, in a paragraph that discussed surface dusts.

Mr. Ewing cites to the EPA's use of dust sampling in Libby as condoning the use of D5755 by Claimants' experts. However, the EPA[19] in Libby "is not relying upon measured dust levels to decide if residential/commercial sources [of asbestos] must be addressed". After the EPA cleans a property, only visual inspection of the property and aggressive air sampling will be used to determine cleanliness. The EPA chose air sampling for clearance testing because asbestos in surface dust is not "directly correlated with risk estimates", while air concentrations directly correlate with risk estimates. (page 11)

5.1 Resuspension of Surface Dust

Both Ewing and Longo suggest that surface dust that contains asbestos may be resuspended in the air, thus causing an exposure to a building occupant or worker. They cite this action as one justification for surface dust

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[17] COPC Committee (2003). "World Trade Center Indoor Environment Assessment: Selecting Contaminants of Potential Concern [COPC] and Setting Health-Based Benchmarks", contributors included the US EPA, OSHA, and ATSDR, p. 11.
[18] Chatfield, E. J. and Kominsky, J. R. (2001). "Summary Report: Characterization of Particulate Found in Apartments After Destruction of the World Trade Center".
[19] US EPA (2003). "Libby Asbestos Site Residential/Commercial Cleanup Action Level and Clearance Criteria: Technical Memorandum", Draft Final, December 15, 2003, p. 5.

sampling. Lee[20] has investigated airborne concentrations in buildings that were allegedly damaged by the 1995 Northridge earthquake and compared these with surface dust concentrations determined using the ASTM D5755 method. As can be seen in the following graph (Figure 6), there was no correlation between asbestos in air and surface dust.

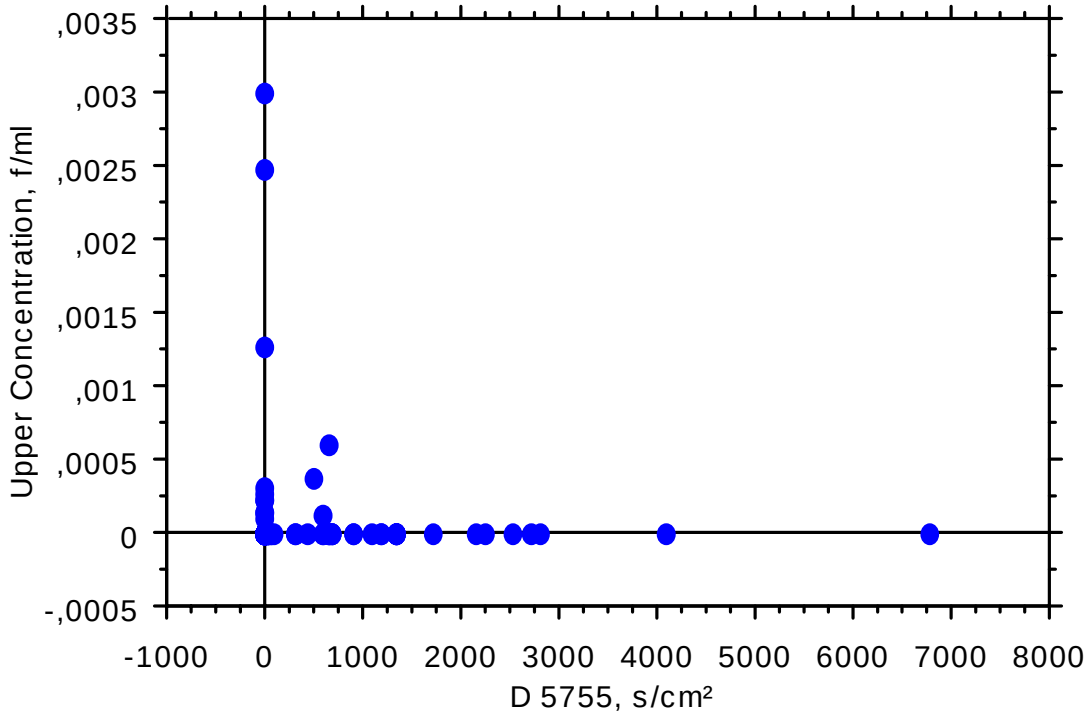


Figure 6. The correlation of airborne asbestos and asbestos in surface dust from 142 homes allegedly damaged during the 1995 Northridge earthquake.

The EPA has reported a similar graph (Figure 7) from studies they have conducted in Libby, MT. As in the Lee data, the vast majority of data points show either some reportable dust concentration with zero airborne asbestos or some airborne asbestos with zero asbestos in the surface dust. The EPA's data are shown in Figure 7.

[20] Lee, R. J., Van Orden, D. R., and Stewart, I. M. (2000). "Dust and Airborne Concentrations – Is There a Correlation?", *Advances in Environmental Measurement Methods for Asbestos*, ASTM STP 1342, M. Beard and H. Rook, Eds., American Society for Testing and Materials, p. 313 – 322.

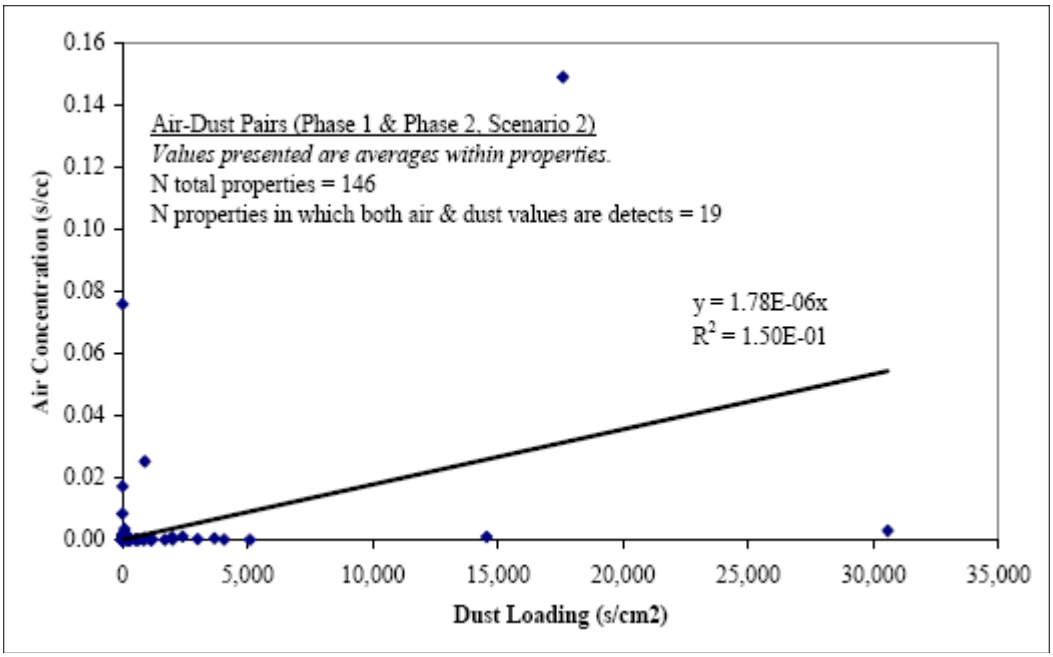


Figure 7. The correlation of airborne asbestos and asbestos in surface dust reported by the EPA from homes in Libby, MT. The vast majority of samples reported some dust loading, but no airborne concentration.

These data show there is no correlation between the amount of asbestos in surface dusts and the amount that is airborne. Because there is no correlation, there cannot be any relationship between the asbestos in surface dust and the amount that can be breathed by a building occupant or worker. These data support the statement from the ASTM D5755 method which states: "no relationship has been established between asbestos-containing dust as measured by this method and potential human exposure to airborne asbestos".

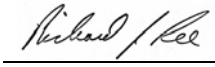
5.2 Determination of Dust Morphologies

The use of the method to suggest there are "free respirable size asbestos fibers & bundles" in the surface dust, as suggested by Dr. Longo and Mr. Ewing, is not an accepted practice. Because of the liberation of fibers from particles during the sample preparation, the analyst cannot determine whether the free fibers observed in the transmission electron microscope occurred on the surface in that manner or were liberated from larger particles during the sample preparation procedure.

RJ Lee Group tested a vermiculite-containing fireproofing material[21] to determine if free, respirable fibers became airborne as a result of hand crumbling the materials. Approximately 10gm samples of fireproofing were hand-pulverized over a 5-10 minute period until a majority of the pulverized material was smaller than 5mm. Air samplers were set up about 6 inches

[21] RJ Lee Group, Inc. (1992). Crumbling Experiment.

below and 6-12 inches laterally displaced from the point of crumbling. In addition, one sampler was located about 42 inches below with a 12 inch lateral displacement. Two samplers were placed in the debris stream directly below the point of crumbling. This arrangement permitted monitoring the air concentration during (5-10 minutes), after (20 minutes), and overall during the experiments. Over 40 experiments were conducted – no free asbestos fibers were observed on any air filter. Experiments conducted by Chatfield[22] on six asbestos-containing materials (including a fireproofing material with chrysotile, vermiculite and gypsum) support this finding.



Richard J. Lee
President

[22] Chatfield, E. (2000). "Correlated Measurements of Airborne Asbestos-Containing Particles and Surface Dust", *Advances in Environmental Measurement Methods for Asbestos*, ASTM STP 1342, M. Beard and H. Rook, Eds., American Society for Testing and Materials, p. 378 – 402. Criticisms of this test by Dr. Longo are in error. Dr. Longo does not apply the correct principles of particle coagulation as described in authoritative texts such as those by Friedlander, Hinds, and Baron/Willeke.